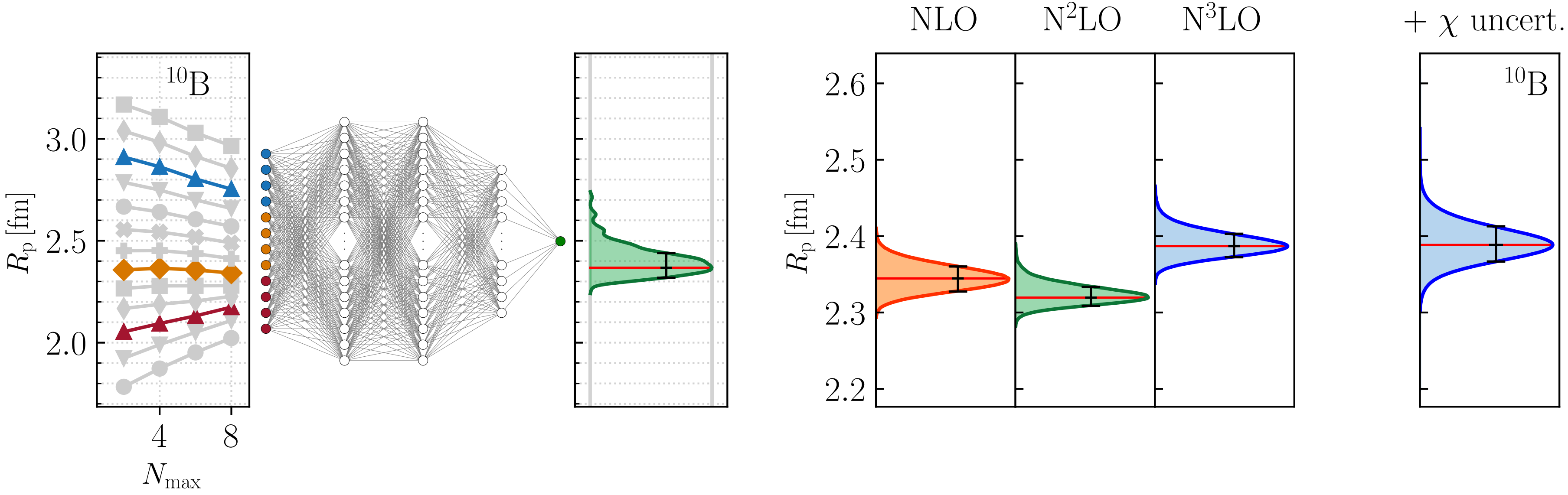
# Precision NCSM Calculations of Nuclear Radii

NCSM Calculations → Data Evaluation → Post-Processing → Final Prediction

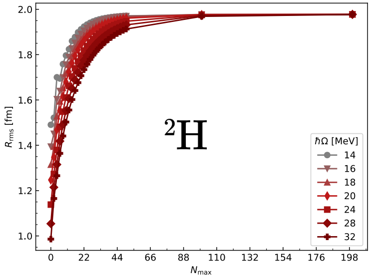


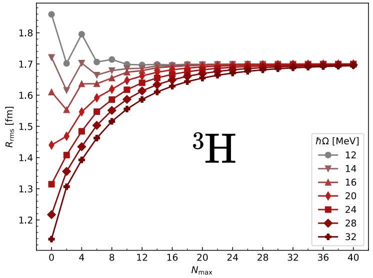
# Artificial Neural Networks

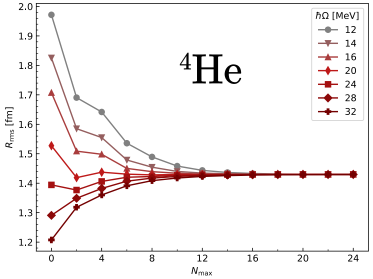


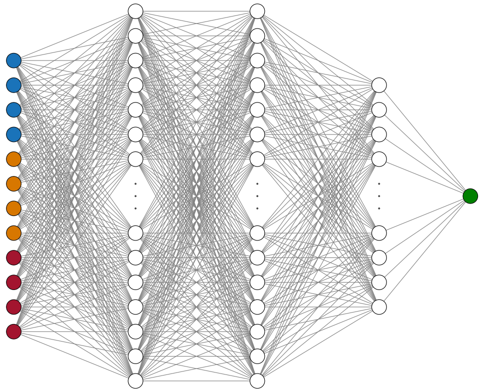
Network training

- Utilizing pattern recognition capability
- Network has to be trained
- Trainings data from converged calculations



Multiple networks can be constructed and trained



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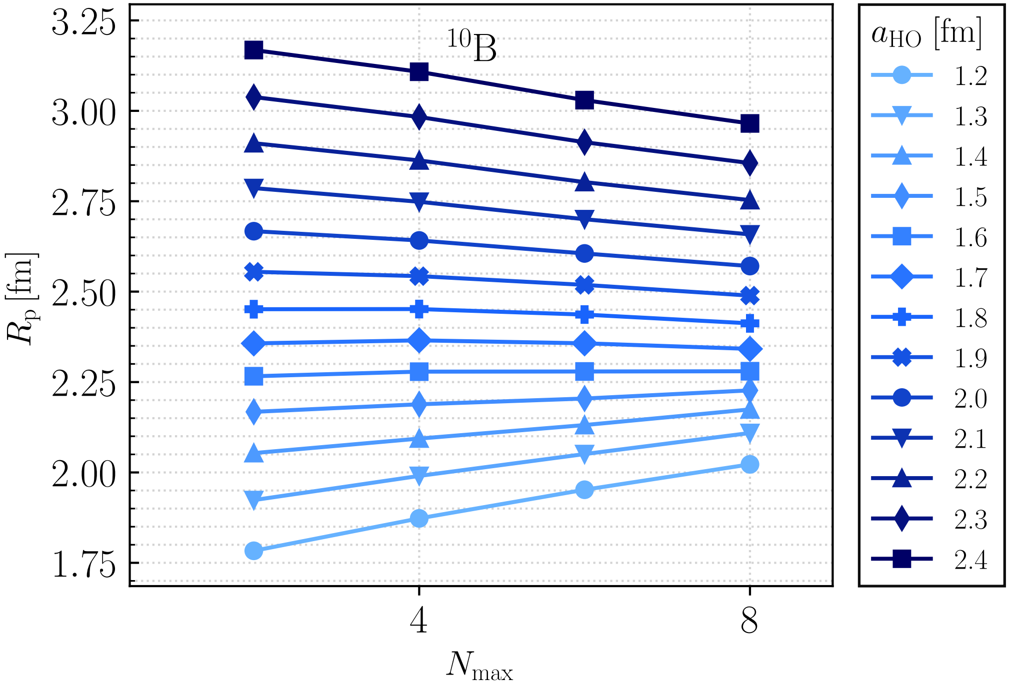
# NCSM Data

NCSM Calculations | Data Evaluation | Post-Processing | Final Prediction

- Range of $N_{\max}$ and $a_{\mathrm{HO}}$
- Insufficient convergence
- Extrapolations necessary

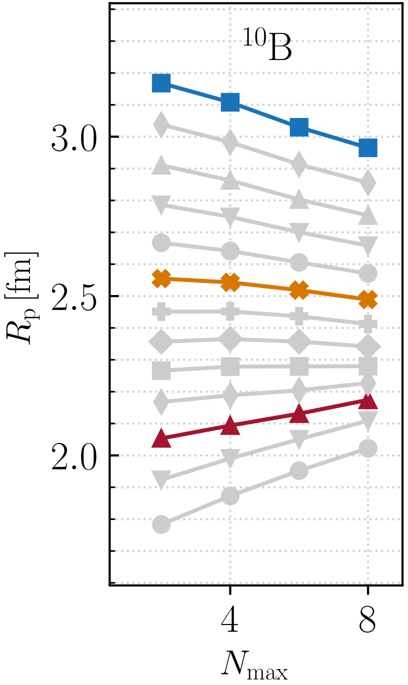


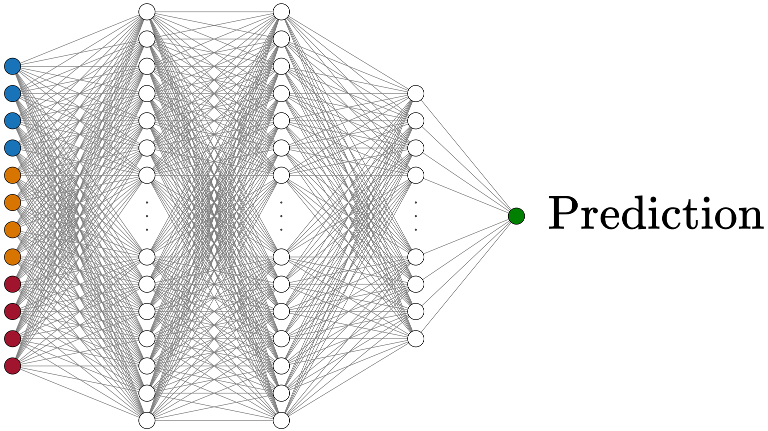
# ANN Extrapolations



NCSM Calculations | Data Evaluation | Post-Processing | Final Prediction

- Samples as input for ANNs
- 3 $a_{HO}$ at 4 consecutive $N_{max}$
- Constructing distribution from ANN predictions



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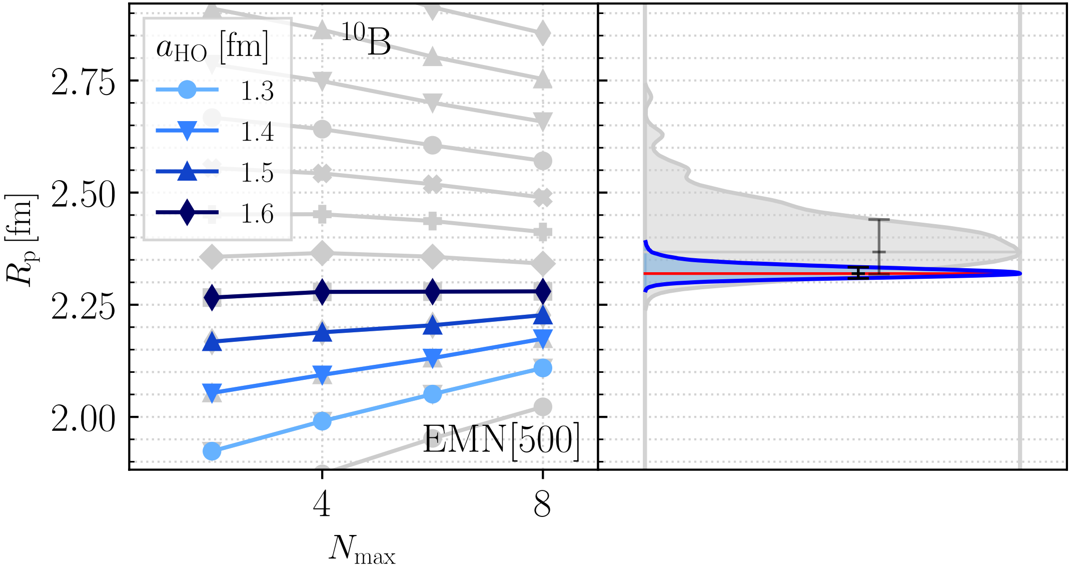
# Pre-Selection



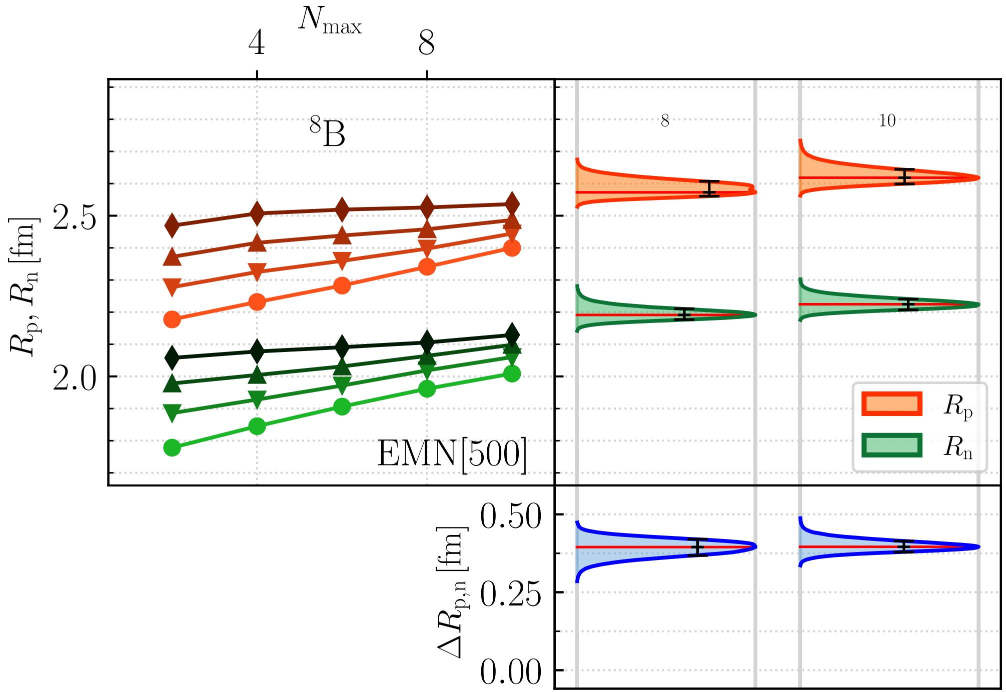
- Mitigating unwanted artifacts in histogram
- Selecting 4 flattest ascending $a_{HO}$ sequences
- Statistical analysis extracts many-body and network uncertainties



# Radius Differences

NCSM Calculations → Data Evaluation → Post-Processing → Final Prediction

- Sample-wise subtraction of ANN predictions
- New distribution inherently includes correlations
- Errors smaller compared to classical propagation of uncertainty



# Bayesian Analysis

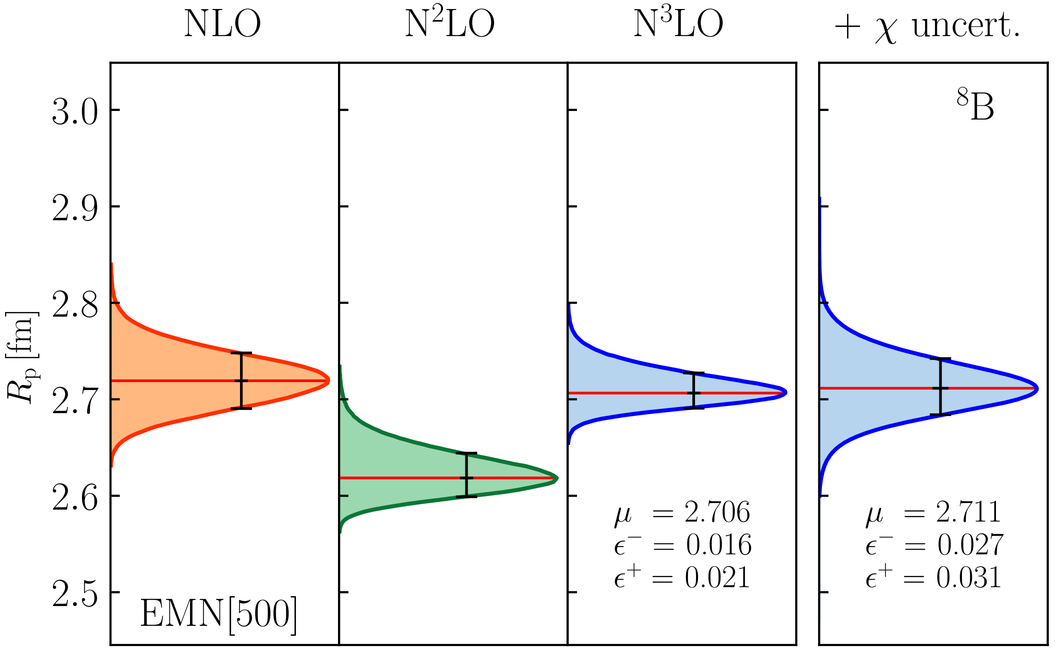
NCSM Calculations → Data Evaluation → **Post-Processing** → Final Prediction

| Family | | | |
|---|---|---|---|
| EMN | NLO | $N^2LO$ | $N^3LO$ |
| SMS | NLO | $N^2LO$ | $N^4LO+$ |

## BUQEYE

- Estimate effect of missing higher orders
- Select most probable value from each order's histogram
- Combine many-body and interaction uncertainties

J.A. Melendez et al. Phys. Rev. C 100, 044001 (2019)



# Point-Proton Radii

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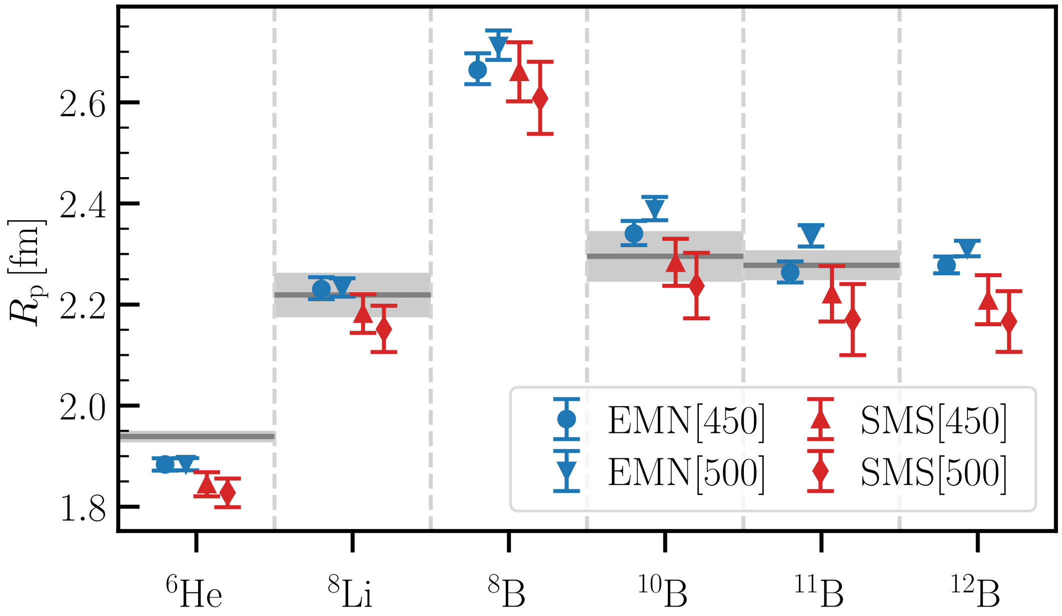
NCSM Calculations → Data Evaluation → Post-Processing → Final Prediction

- Predictions including many-body and chiral uncertainties
- Compared to experimental data (if available)
- Compatible results from both interaction families



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# Proton-Neutron Radius Differences

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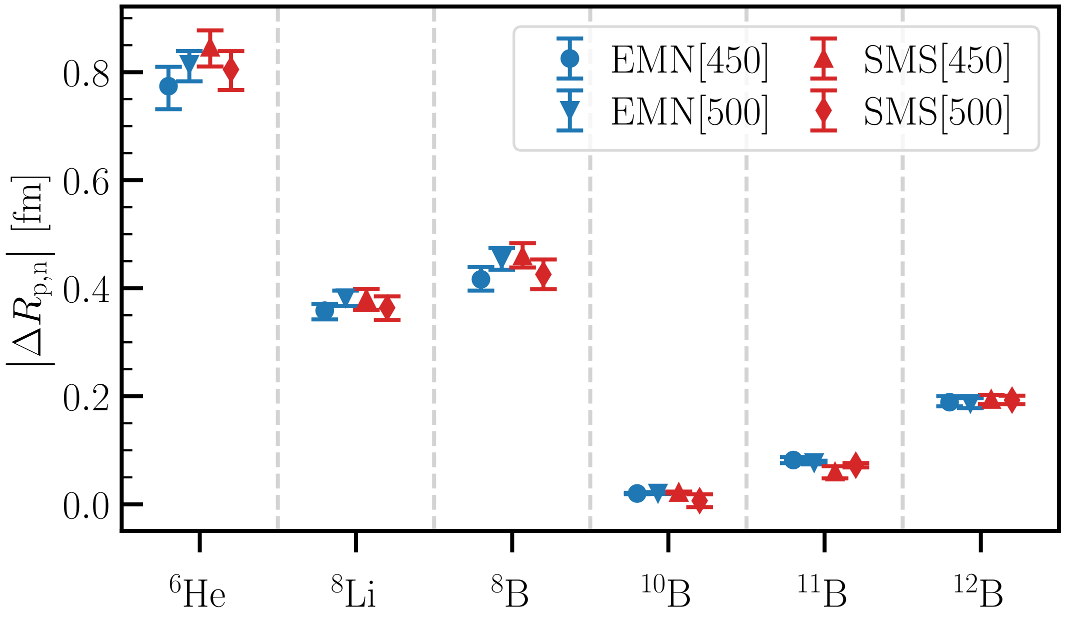
- Radius differences in much better agreement across interactions
- Larger proton-neutron radius difference for $^{8}$B
- $^{6}$He as accepted halo nucleus



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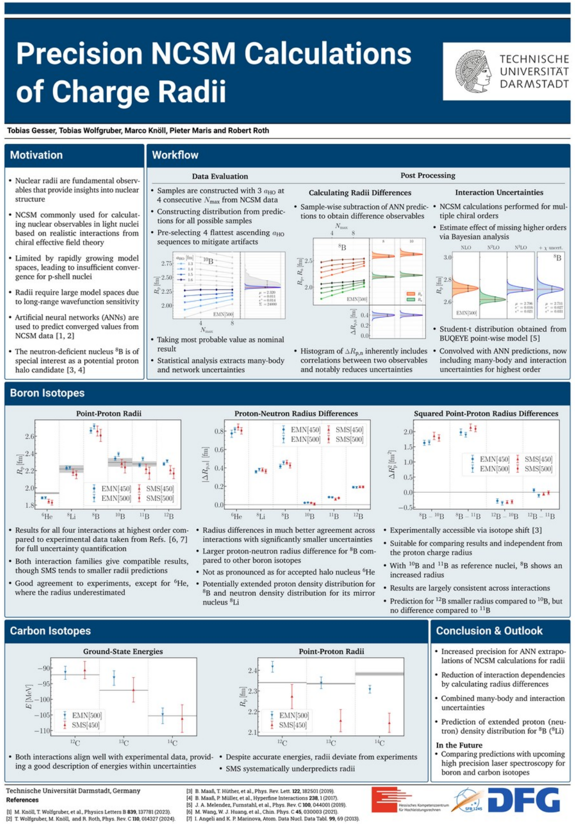


# Thank you for your attention!

Find more details on my poster

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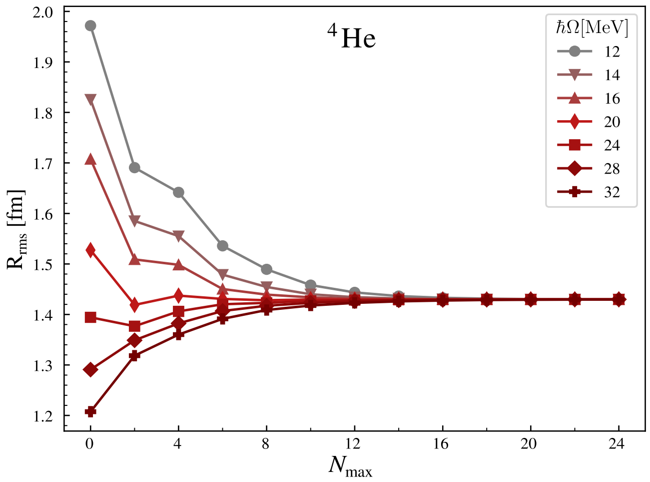
# NCSM

NCSM Calculations → Data Evaluation → Post-Processing → Final Prediction

Convergence reached for few-body systems



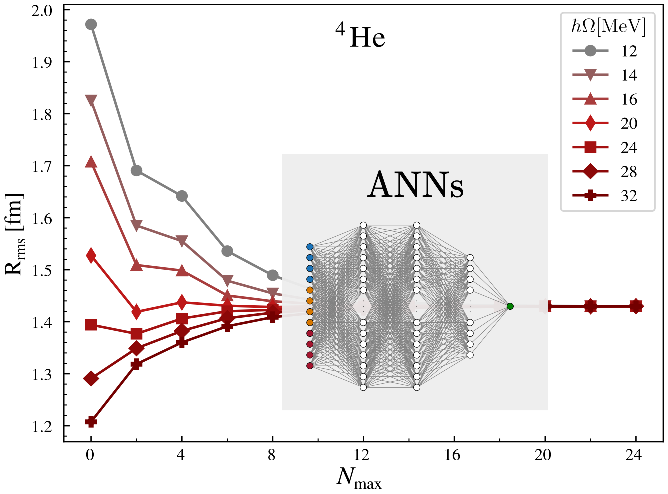

Interactions derived from chiral EFT

- non-local (EMN)
- semi-local (SMS)

# NCSM

NCSM Calculations | Data Evaluation | Post-Processing | Final Prediction

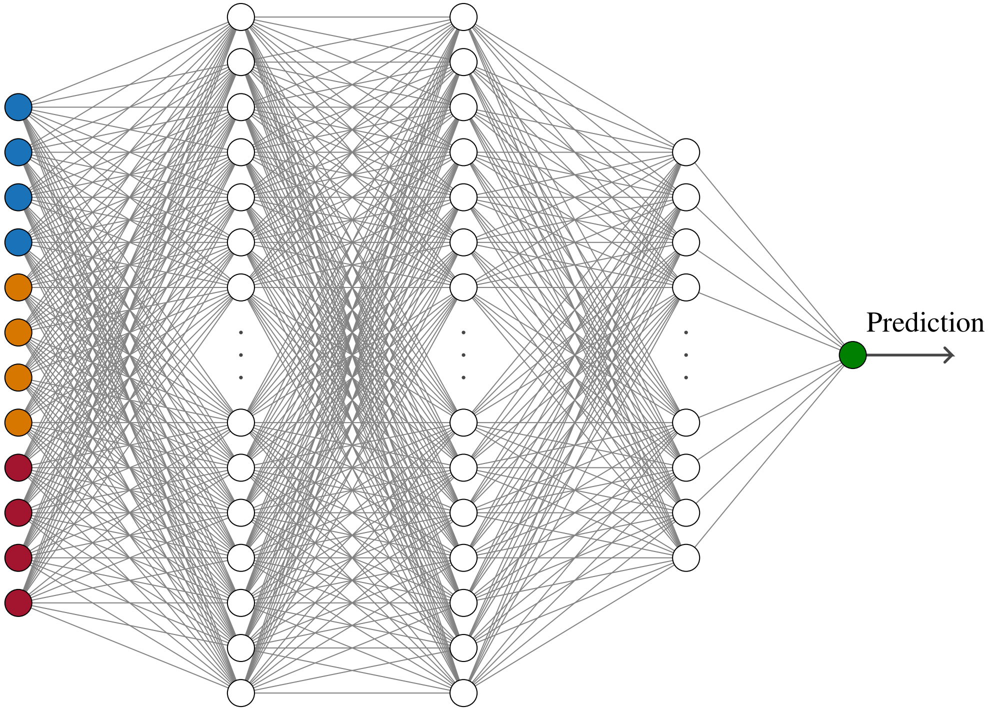
- For different oscillator frequencies or lengths
- Convergence reached for few-body systems




Interactions derived from chiral EFT

- non-local (EMN)
- semi-local (SMS)

Extrapolations necessary for heavier nuclei




Wolfgruber, T et al., arXiv:2310.05256, 2023

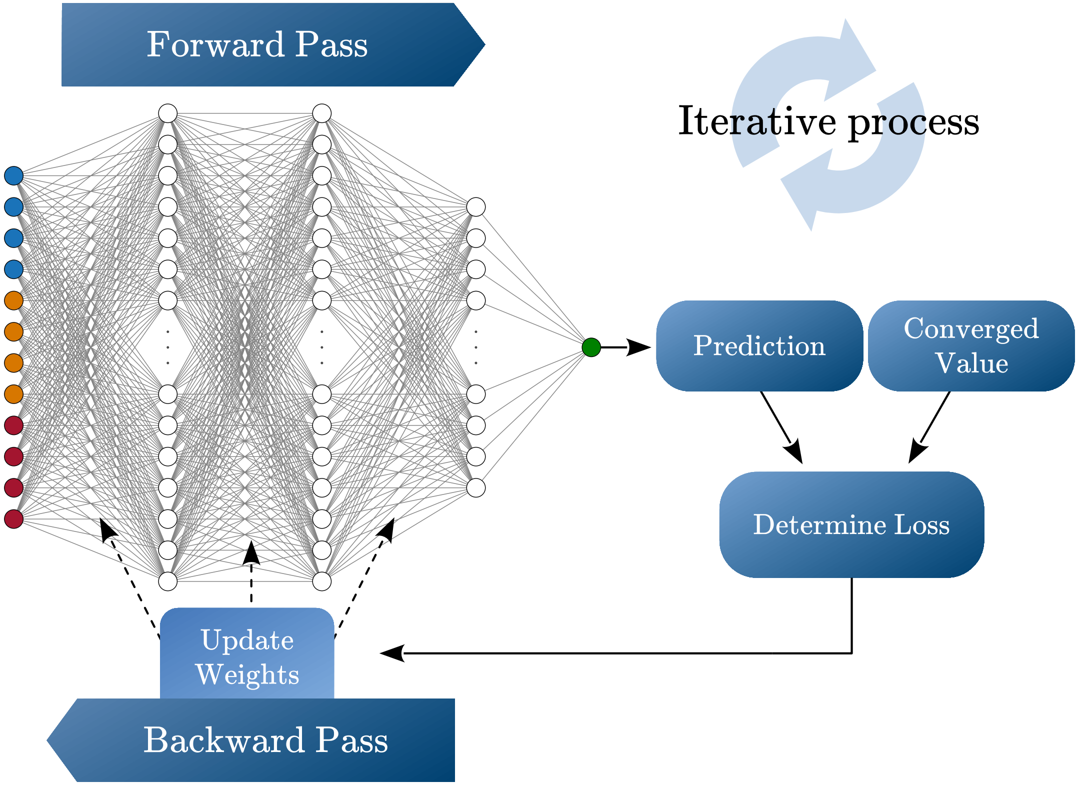
# Artificial Neutral Networks



- Dense feed forward network

Requires training to capture convergence behavior

- Multiple networks for multiple predictions



# References


- M. Knöll et al., Phys. Lett. B 839, 2023.
- T. Wolfgruber et al., arXiv:2310.05256, 2023
- B. Maaß et al., Phys. Rev. Lett. 122, 2019.
- W.G. Jiang et al., Phys. Rev. C 100, Nov. 2019.
- P. Maris et al., Front. Phys. 11, Apr. 2023.